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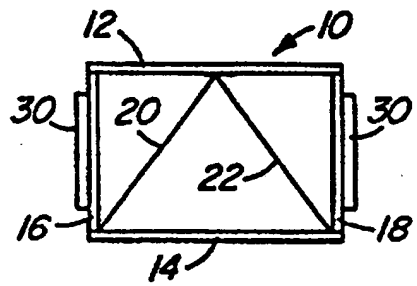
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(54) Title: **PREMANUFACTURED STRUCTURAL ELEMENTS**

(57) Abstract

A structural element that may be used to reinforce those structures or portions of structures that respond to loads in the manner of a diaphragm or shell. The units are particularly appropriate in designing structures to adequately resist earthquake, wind and other loads. The structural elements may be installed in a new building or retrofitted in existing buildings. The element (10) has top and bottom members (12, 14) and two side members (16, 18) in a substantially rectangular configuration, the top and bottom members (12, 14) have flat top and bottom exterior surfaces. Inclined brace members (20, 22) fit within the rectangular configuration connected to the top and bottom members (12, 14) and the two side members (16, 18) to form a structurally rigid element. The elements (10) may be made from any material and may be joined by any method that provides the necessary rigidity. Preferably the elements are premanufactured in the factory.



PREMANUFACTURED STRUCTURAL ELEMENTSTechnical Field

The present invention relates to a structural element that may be used to reinforce those structures or portions of structures that respond to loads in the manner of a diaphragm or shell. The units are particularly appropriate in designing structures to adequately resist earthquakes, wind and other loads.

Background Art

10 The Canadian Building Code calls for balanced design with symmetry relative to building loads and states that abrupt section changes which create load concentration should be avoided. This is consistent with fundamentally sound design. For example the structural systems of living beings are equalized in the sense that bearing sections, dimensions and their response to dynamic and static loads are equalized relative to stress. The aesthetic appeal of natural things is often our reaction to complex symmetry. The design theory of nature is the ultimate version of "limit state design" a theory only recently adopted and, as yet, not much followed in engineering practice.

Natural structures avoid sudden changes in structural sections or erratic patterns of resistance. Most living things have at least one axis or plane of symmetry. A tree trunk is a perfect example. No tree has a smaller section at the bottom than at the top.

Man-made structures are subject to the same physical laws and therefore one should expect a similar degree of equalization.

Abrupt section changes which create load concentrations are not recommended. However, there are many structures that depart from these principles and from code recommendations. Generally it is buildings that have been well engineered that are able to satisfy the balanced design criteria. The housing industry generally tends to lag behind this balanced design criteria.

Recurring experiences with earthquake activities, high winds, and other unusual loads or load combinations, show up problems of ignoring balanced designs and there is a need, particularly in framed structures, to ensure that buildings do have a balanced design. There is also a need to reinforce existing structures to withstand loadings.

U.S. Patent 4,947,612 discloses a bracing system for adjoining joists that is used to increase structural resistance to loads acting in a direction perpendicular to the plane of the structure.

Disclosure of Invention

The present invention provides a series of structural elements designed to improve load transfer capacity in building roof, wall and floor diaphragms, and to provide increased stress and balanced resistance to earthquakes and other loads. Alternative types of the elements may be installed in various areas of the building so as to provide stiffness as required by structural design. The configuration enables effective attachment and thus effective incorporation of the stiffness of the element into the entire structure.

In contrast to the bracing system of the above United States Patent 4,947,612, the structural elements

of the invention increase structural resistance to loads acting within the plane of the structure.

The structural elements may be used to transfer vertical and horizontal forces from an upper wall to a lower wall and also to provide vertical and horizontal load transfer within the wall. The element may be used as a seismic unit to reinforce stud walls, floors and roofs and the like.

The structural elements installed within a frame building provide a high degree of control over the path by which wind, earthquake, and other loads travel to the foundations of the building. The elements provide effective shear reinforcement for diaphragm structures, for example walls, floors and roofs and around structurally relevant openings in diaphragm planes.

Shear loads in walls, roofs, floors and other diaphragm structures can be transferred within single planes using structural elements of the present invention. Better structural integrity of bonding between walls, floors and roofs is obtained with the use of the structural elements of the present invention. In existing frame buildings, large horizontal forces from earthquakes, wind, etc., and the differences in stiffness and shear resistance of the building elements result in different deflection responses between elements in the building. Thus, the result often causes severe shear forces that nails and other attachments cannot resist. Testing and experience with earthquake and wind disasters have verified that failure between structural assemblies of different stiffness, for example sheeting and studs in conventional wood frame construction, often occurs. When wall sheeting fails, a structure is seriously weakened thereby causing the complete building to be in jeopardy.

The structural elements of the present invention may be inserted between, or used instead of, studs to provide a stiff prefabricated structural unit or assembly with significantly greater rigidity than conventional wood or steel studs. This rigidity and stiffness is achieved by building the structural elements of the present invention with a truss or diaphragm configuration and with joints that have capacity to transfer moments. Thus, there is a lower difference in deflection response between the stud assemblies and the sheeting, and a reduction in shear force on the nails or other attachments. The structural elements and existing studs can be connected using perpendicular to grain nailing and the large area of the wide face of the stud makes adequate connection easy even in close quarters.

In the case of floor joists, the elements may be installed between joists in the plane of the diaphragm to reinforce, stiffen and equalize the design of the structure. This feature creates a substantial increase in the planar stiffness of the diaphragms.

Improvements are provided in structural connections between walls to floors and roofs. The structural elements may be placed in the bearing wall between the floor joists and have the capacity to transfer the loads from the upper wall to the lower wall without passing the wall loads through the joists. Thus, the joists transfer only vertical reaction loads from the adjoining floor. The connection between walls and floors or roofs is generally one of the weakest parts of the building, whereas by utilizing the structural elements these connections become substantially stronger.

The structural elements are formed in a series of standard sizes of different dimensions, and tables are provided showing the allowable forces for the different

elements. An engineer, architect or structural designer calculates the forces according to the building codes and then selects the number and location of elements required.

5           The present invention provides a structural element for earthquake reinforcement of structures comprising: top and bottom members and two side members in a substantially rectangular configuration rigidly connected together, the top and bottom members having flat top and  
10 bottom exterior surfaces, brace members or a diaphragm within the rectangular configuration connected to the top and bottom members and the two side members to form a structurally rigid element.

          The present invention also provides in a frame  
15 structure including floor joists, roof joists and wall studs, the improvement of structural elements according to the present embodiment positioned between joists and/or between wall studs so that stresses in the structure may be balanced. There is also provided a  
20 method of constructing a frame structure utilizing the structural elements to improve response to lateral load and provide a balanced design with symmetry of resistance relative to the external forces from earthquake, wind and the like.

25           According to a preferred embodiment of the invention, the structural elements will be premanufactured, that is manufactured under close control in a factory. This avoids the errors and limitations that occur in on-site building construction. However,  
30 in certain circumstances, particularly, for example, in the case of large structural elements and, particularly where those large structural elements are of steel, it might be desirable to ship them dismantled. In these circumstances, the appropriate provisions for attachment

would be made in the factory. For example, bolt holes might be drilled and all that would be necessary on the site would be the installation of bolts into those holes. This achieves the same precision of control as if the  
5 whole structure had been premanufactured in the factory.

Brief Description of Drawings

In drawings which illustrate embodiments of the present invention,

10 Figures 1A to 1K show schematic drawings of different embodiments of structural elements according to the present invention,

Figure 2 is an elevational view of another embodiment of a structural element according to the present invention,

15 Figure 3 is a sectional view taken at line 3-3 of Figure 2,

Figure 4 is a sectional elevation showing floor joists with structural elements according to the present invention positioned between the joists,

20 Figure 5 is a sectional elevation showing structural elements according to the present invention incorporated into wall studs,

Figure 6 is a sectional elevation showing structural elements according to the present invention incorporated  
25 into walls, floors and roofs,

Figure 7 is a plan view showing structural elements positioned horizontally between floor joists,

Figure 8 is a sectional view taken at line 8-8 of Figure 7,

Figure 9 is a sectional elevation showing another embodiment of structural elements positioned between  
5 joists,

Figure 10 is an elevational view showing structural elements positioned around an opening in a wall, and

Figures 11 and 11A illustrate joints appropriate at the corners of structural elements according to the  
10 present invention.

#### Best Mode for Carrying Out the Invention

Structural elements according to the present invention may be made in different sizes and shapes to comply with any type of structure. The structural  
15 elements may be made from wood, engineered wood, plastics, metals, composite materials, or any material and in any combination of materials that provide the required strength. In the case of plastics, metals or other composite materials, the structural element may be  
20 made as an integral unit cast or formed in one piece. In the case of wood, engineered wood, or other types of composite materials, the structural element may be an assembly of a plurality of pieces that are joined together by wafer joints, mortise and tenon joints,  
25 nailing, gluing, screwing, bolting, truss plate jointing, welding, notching, finger jointing, locking, and by any other means or by any other combination of jointing means to provide a structural rigid element that can transfer the required loads necessary for the building.



As shown in Figures 1A to 1K there are innumerable configurations for the structural element 10, each element has a top member 12 and bottom member 14 with two side members 16 and 18. The top and bottom members 12,14 and the side members 16,18 are generally formed in a rectangular configuration as shown in Figures 1A, 1B, 1C, 1D and 1I. Figure 1E shows an element in the form of a parallelogram wherein the side members 16,18 are substantially vertical. Figure 1F shows an element in the form of a parallelogram wherein the top member 12 and bottom member 14 are substantially horizontal. Figure 1G shows an trapezoidal shaped element with horizontal top member 10 and bottom member 14, and Figure 1H shows an element which has one side member 16 longer than the other side member 18 and the top member 12 is substantially horizontal.

Inclined brace members are provided within the structural element 10. In each case the brace members are connected to the top member 12 and bottom member 14, together with the two side members 16,18. In Figure 1A two brace members 20,22 are provided to make a triangle with the bottom member 14. At the top the brace members 20,22 are joined to the top member 12 and at the bottom the brace members 20,22 are each joined to one of the corners between the side members 16,18 and the bottom member 14. Figure 1B shows a diagonal brace 24 joined to the top member 12 and side member 18 at one corner and the bottom member 14 and side member 16 at the other corner. Figure 1C shows a diamond shaped bracing arrangement 26 wherein the corners 28 occur at the top member 12, bottom member 14 and both side members 16,18. Figure 1D illustrates two diagonal members 24 in the form of a cross. Figure 1E shows a diamond shaped brace 26 similar to that shown in Figure 1C. It is noted that Figure 1C shows an offset diamond arrangement, whereas Figure 1E shows a diamond with opposed sides of equal

length joining the centers of the top member 12, bottom member 14 and each of the side members 16,18.

Figure 1F shows two diagonals 24 in the shape of an X similar to that shown in Figure 1D. Figures 1G, 1H and 5 1I all show triangular configurations similar to that shown in Figure 1A except in the case of Figure 1I the top of the triangle does not occur at the center of the top member 12.

Figure 1J shows an element similar to the other 10 rectangular elements but having an extension to the side member 16 to provide an additional joining member within the building structure. Figure 1K illustrates a long element with parallel chords and with the two ends having member 20 connecting to corners and intermediate bracing 15 members 22 positioned between the end bracing members. The number and arrangement of members may be varied to suit the required length and shape. Whereas the drawing shows that the side members 16,18 are short, in another embodiment the top member 12 and bottom member 14 may be 20 short and the side members 16,18 long.

Figures 2 and 3 illustrate an element wherein the inclined members are replaced by a diaphragm sheet 26 between the top, bottom and side members.

The top member 12 and bottom member 14 have flat 25 exterior surfaces. In one instance the side members 16,18 have flat exterior surfaces. In another embodiment as shown in Figure 1A, intermediate members 30 are provided for I-shaped joists so as to interface with the abutting web surfaces and the internal flange surfaces of 30 the joists.

Whereas examples of the structural elements 10 are illustrated in Figures 1A to 1K, other shapes may be

provided to adequately match specific configurations required for joists, studs or floor installation. Joist includes any beam, truss, girder, or other structural entity, a stud includes a column, post, or similar structural entity, as does the floor structure.

Figure 4 illustrates structural elements 10 positioned between floor joists 34 with a floor 36 on top. Upper wall studs 38 and lower wall studs 40 are shown at any spacing and not necessarily at the same spacing as the joists 34. By utilizing the structural elements 10, it becomes unnecessary to have the wall studs 38 and 40 positioned directly over the joists 34.

Figure 4 illustrates the recessing of the upper surface of the floor joist 34 beneath the floor 36. This is a method of ensuring that the load is carried by the structural members of the invention. It is possible that the member 34 could be flush or proud with the top surface of the structural element 10. Flush would achieve the same effect as the structure shown in Figure 4, that is ensuring that the load is distributed. Even when the joist 34 is proud, it will typically be compressed under the influence of a load to ensure that the floor 36 rests on the member 10. The preferred approach is that illustrated in Figure 4.

Figure 5 illustrates an element 10 positioned between wall studs 38. The connection between the element 10 and the studs are shown to be bolts 42 but may be by nailing, gluing, screwing, gussets, welding, notching, locking, and any other means or by any combination of joining means to ensure sufficient rigid connection for the transfer of the required loads.

Figure 6 illustrates a combination of elements 10 positioned between wall studs 38,40 and between joists 34

below floors 36. As may be seen, the structural elements 10 need not all be square but are designed to fit within the dimensions of the building. The element 10 on the right, is of the type shown in Figure 1K which is a long element with a plurality of brace members extending between side members. In one embodiment the structural elements may be incorporated into a new building. Alternatively, the structural elements 10 may be provided for retrofitting into existing building structures.

Figure 7 illustrates structural elements 10 positioned horizontally between floor joists 34. Thus, as required for the specific design of a structural frame, the structural element or elements may be positioned vertically or horizontally to take into account the horizontal and vertical forces in a building. As shown in Figure 8, the element 10 only extends for a portion of the depth of the joists 34.

Figure 9 illustrates another installation of a structural element 10 of the type shown in Figure 1J. As can be seen, the extended member permits additional nailing or other type of attachments to the joists 34. Figure 10 shows a wall with an opening 44 therein. Structural elements 10 are positioned between the studs 38 all around the opening to provide a reinforcement in the diaphragm plane and the balanced resistance to side forces on the wall.

Details of joints appropriate in the structural element 10 are shown in Figures 11 and 11A. Figure 11 illustrates that simple mortise and tenon joints may be used to connect the top member 12, bottom member 14 and side members 16 and 18. Figure 11A illustrates the use of simple wafers. Both these joints are known. Truss plates or finger joints may also be used. The dimensions of the mortise and tenon joint and of the inserted wafer

style joint will be selected depending on the required strength of the structure. Glue may be used to ensure that the structure and integrity of the element is maintained.

- 5           The above has described frame structures but the elements of the invention may be used between the two skins of a double skin inflated structure. The elements may be inflatable. The elements may be integral with, or separate from, the structure. This aspect of the
- 10 invention finds particular application as a reinforcement around an opening in an inflatable structure.

Various changes may be made to the embodiments shown herein without departing from the scope of the present invention which is limited only by the following claims.

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## WE CLAIM:

1. A building unit adapted for abutting connection to an existing building structure and disposed relative to said existing building structure to resist shear forces developed within said building structure, including shear forces parallel to a shear wall or shear floor surface of said building structure resulting from wind loading and seismic activity and to transfer high static, dynamic and reversible loads to adjacent abutting building structure, said building unit comprising:
- 5
- 10 a plurality of structural elements;  
each said structural element comprising:  
generally opposing first and second members, and generally opposing third and fourth members connected in a substantially rectangular configuration, each said element having length and width dimensions that are greater than either cross sectional dimension of said members, said structural element having length and width dimensions derived from said members length and width dimensions and a depth dimension no greater than the maximum cross-sectional dimension of any one of said members so that said substantially rectangular configuration has rectangular length and width dimensions greater than its depth dimension;
- 15
- 20
- 25 opposing first and second members having flat surfaces on the outside perimeter of said substantially rectangular configuration adapted for abutting contact with comparably flat surfaces on other of said structural elements and on existing surfaces of said building structure;
- 30
- inclined brace members within the rectangular configuration connected to the generally opposing first and second members and the third and fourth members to form a structurally rigid element;
- 35
- means rigidly attaching each said structural element to a neighboring one of said plurality of structural elements by attaching said abutable flat perimeter

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member surfaces to comparably flat surfaces on other of said structural elements or on existing surfaces of said building structure.

- 5 2. A building unit as claimed in Claim 1, wherein each said structural element of said building unit includes substantially planar surfaces adjacent said abutable flat perimeter surfaces and wherein said structural elements are rigidly attached to said neighboring elements in a manner that aligns said substantially  
10 planar surfaces to form a substantially continuous coplanar extended surface adapted for the attachment of sheathing to said extended surface.
- 15 3. A building unit as claimed in Claim 2 in which the structural elements are made from materials selected from the group consisting of wood, engineered wood, plastic, metal and composite material.
- 20 4. A building unit as claimed in Claim 2 in which the material of construction is wood and in which the structural elements are joined together with mortise and tenon or wafer joints.
- 25 5. A building unit as claimed in Claim 2 in which the structural elements are formed of wood with said first, second, third, and fourth members joined at corners by finger joints.
- 30 6. A method of constructing a frame building structure that resist shear forces developed within said building structure, including shear forces parallel to a shear wall or shear floor surfaces of said building structure resulting from wind loading and seismic activity, and capable of transferring high static, dynamic, and reversible loads to adjacent building structural

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components and capable of a high level of energy absorption, said method comprising the steps of:

forming a plurality of structural elements including the steps of:

5 providing first, second, third, and fourth linear members; each said member having length and width dimensions that are greater than either cross-sectional dimension of said members;

10 attaching said first, second, third, and fourth members into a substantially rectangular configuration wherein said first and second members are generally opposing each other, and said third and fourth members are generally opposing each other;

providing linear brace members;

15 attaching said brace members within the rectangular configuration by connecting said brace members in an inclined manner to the generally opposing first and second members and the third and fourth members to form a structurally rigid structural element;

20 said structural element having length and width dimensions derived from said members length and width dimensions and a depth dimension no greater than the maximum cross-sectional dimension of any one of said members so that said substantially rectangular  
25 configuration has rectangular length and width dimensions greater than its depth dimension;

said opposing first and second members having flat surfaces on the outside perimeter of said substantially rectangular configuration adapted for abutting contact  
30 with comparably flat surfaces on other of said structural elements and on existing surfaces of said building structure; and

installing said structural elements into said frame including the steps of:

35 placing said structural elements adjacent existing building components so that applied shear forces are incident against one of said perimeter surfaces; and



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rigidly attaching each said structural element to a neighboring one of said plurality of structural elements by attaching said abutable flat perimeter member surfaces to comparably flat surfaces on other of said structural elements or on existing surfaces of said building structure.

7. The method as in Claim 6, wherein said comparably flat surfaces on adjacent surfaces of said building structure are selected from the group consisting of, surfaces of neighboring wall studs, and surfaces of neighboring floor joists and neighboring wall plates:

8. The method as in Claim 7, wherein said step of placing said structural elements adjacent existing building components further includes the step of placing said structural elements with the space between said wall studs or floor joists and sheathing applied to at least one side of the structure formed by said wall studs or floor joists, so that said structural elements are enclosed within said wall studs or floor joists by said sheathing.

9. The method as in Claim 8, wherein said step of placing said structural elements adjacent to other building components comprises placing said plurality of structural elements around at least one side of a structural discontinuity in said framed building.

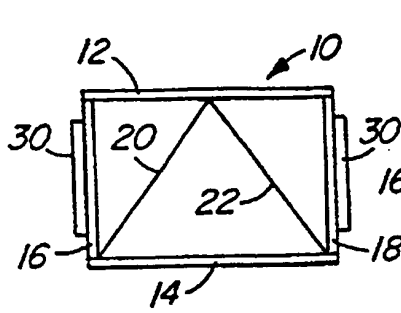


FIG. IA

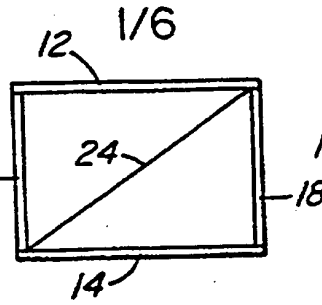


FIG. IB

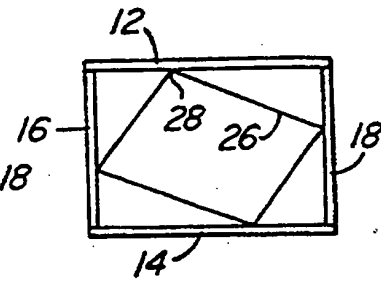


FIG. IC

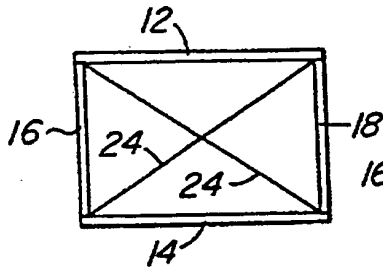


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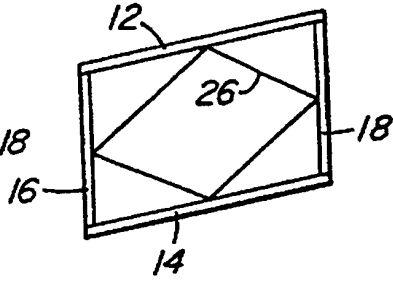


FIG. IE

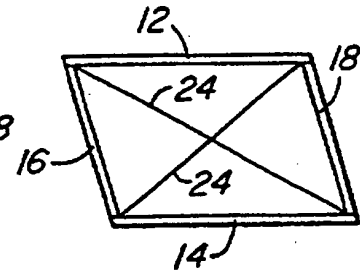


FIG. IF

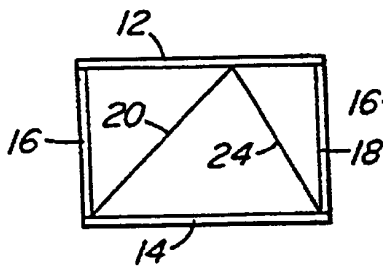


FIG. II

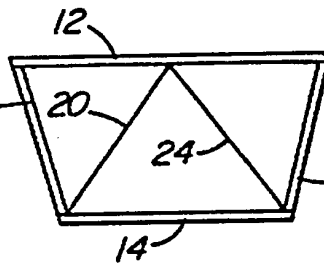


FIG. IG

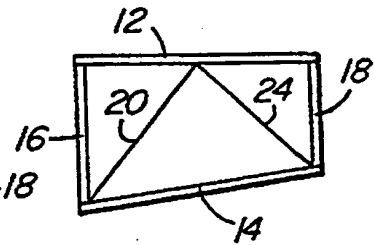


FIG. IH

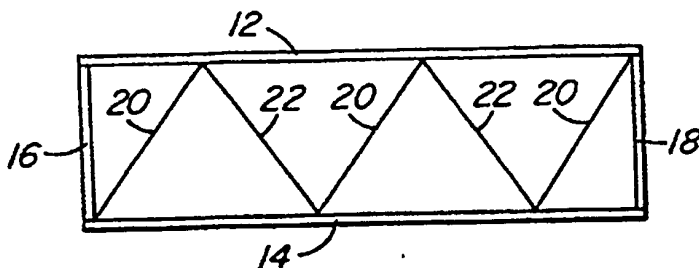


FIG. IK

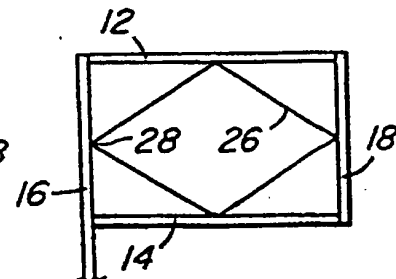


FIG. IJ

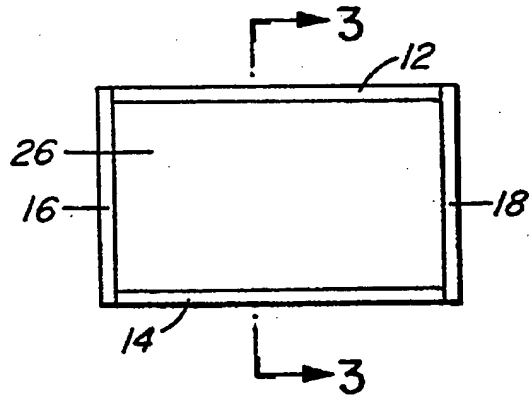


FIG. 2

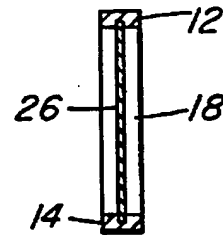


FIG. 3

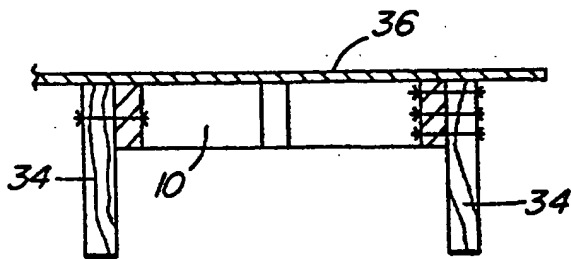


FIG. 8

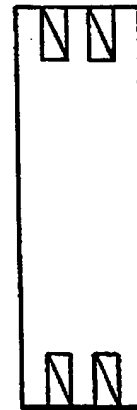


FIG. 11



FIG. 11A  
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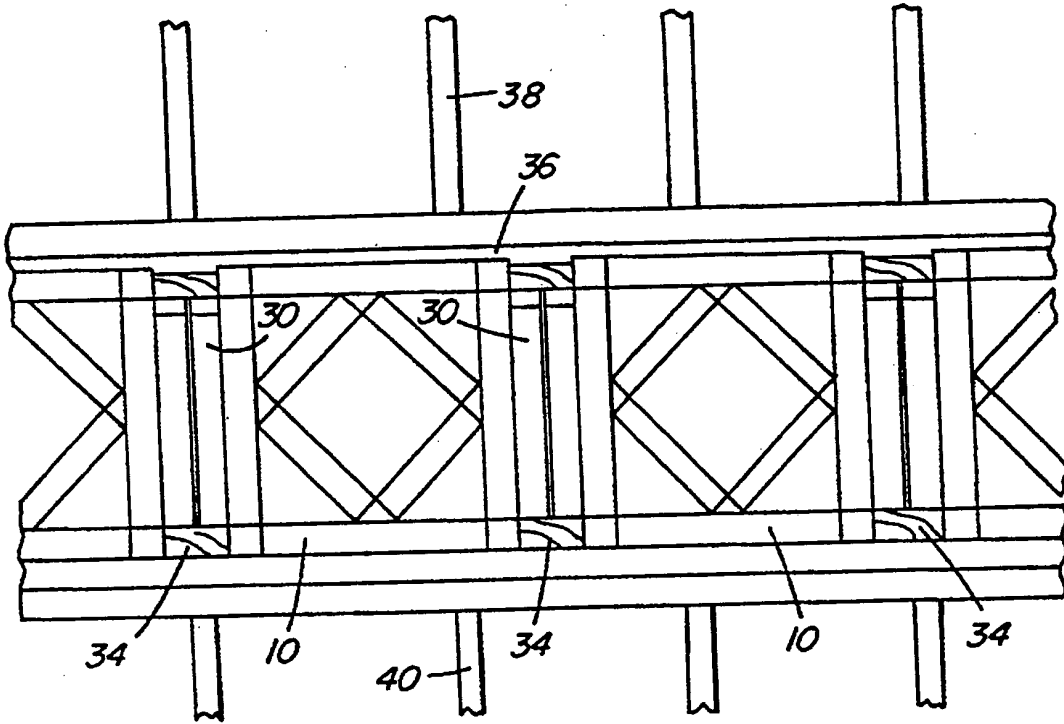


FIG. 4

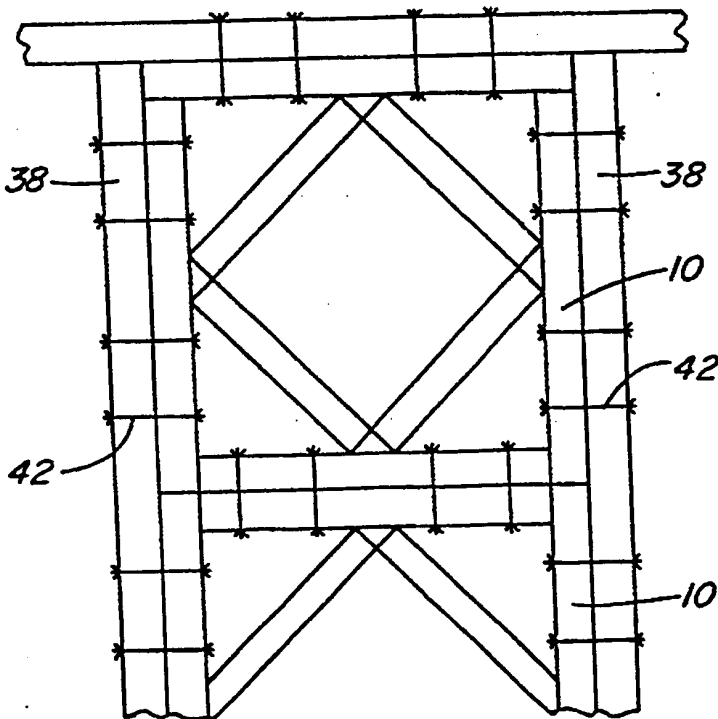


FIG. 5  
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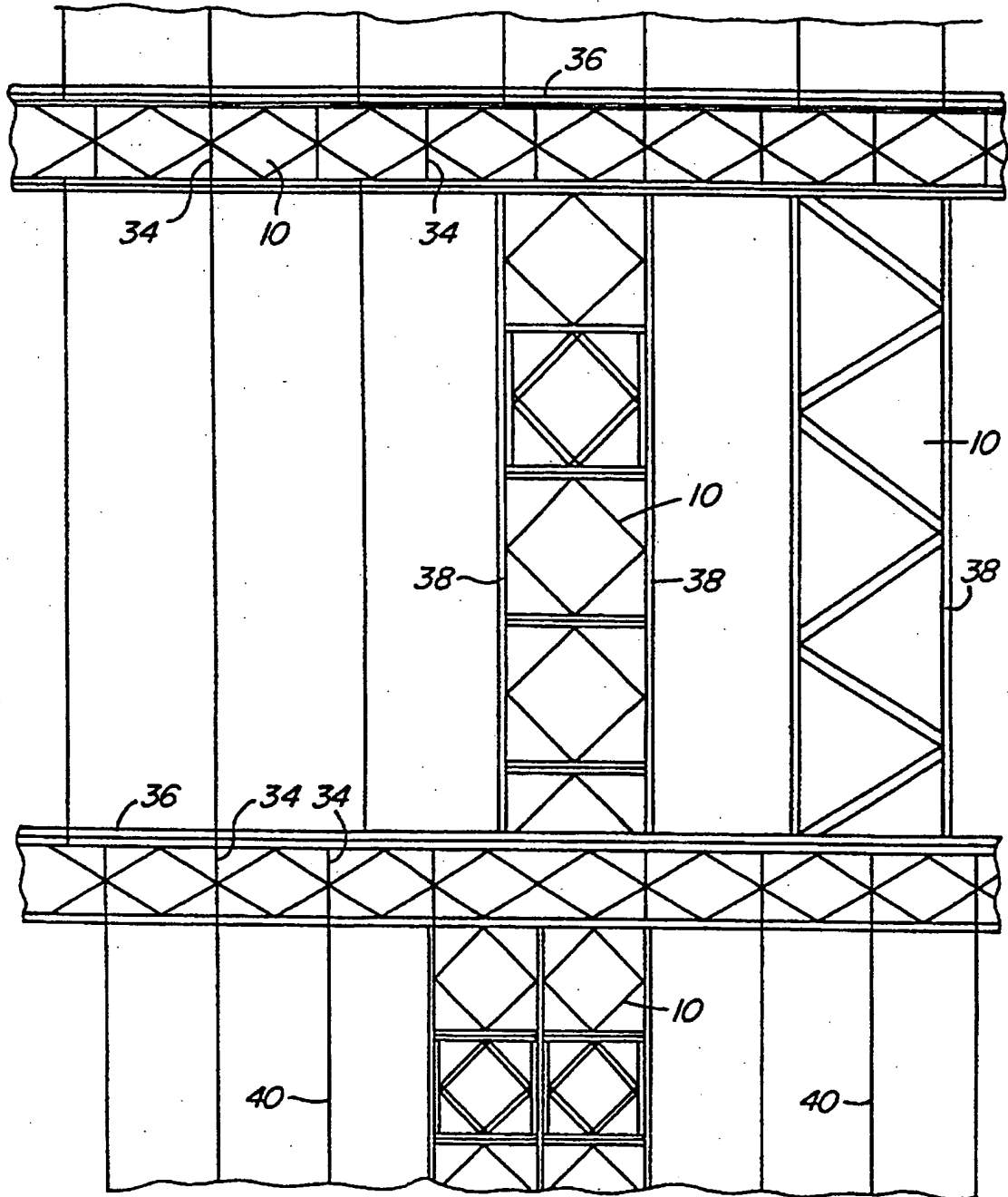


FIG. 6

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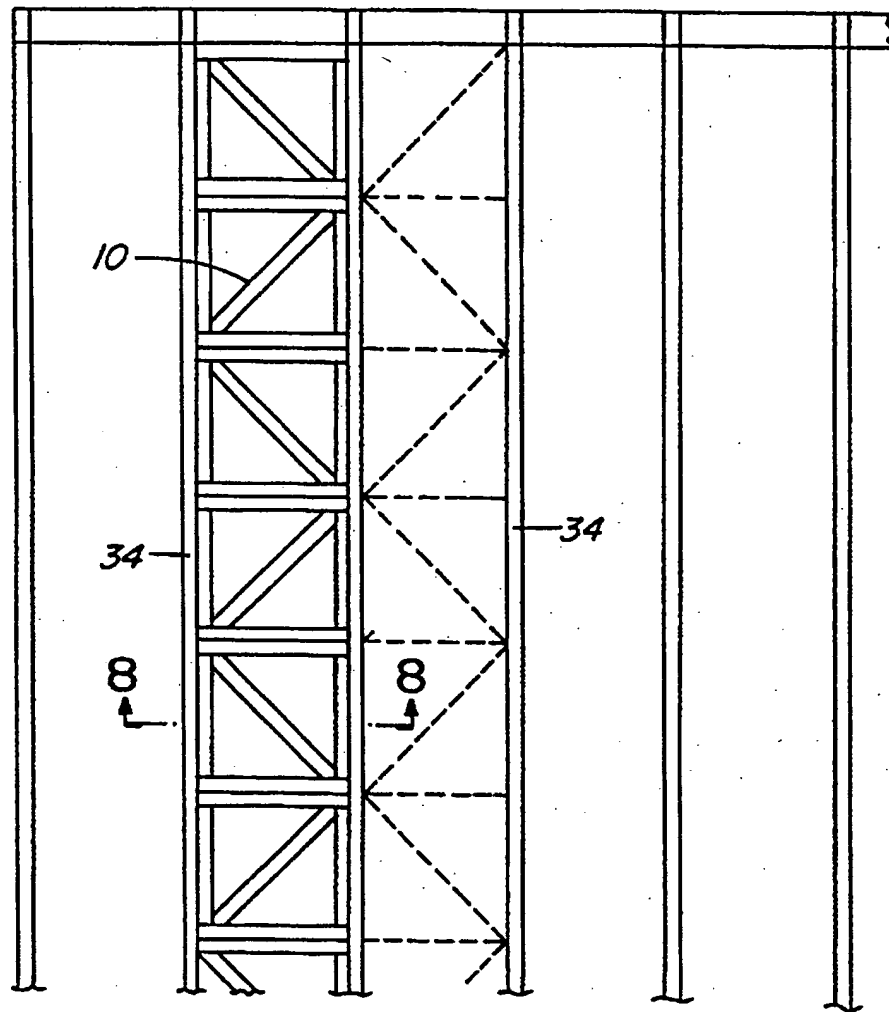


FIG. 7

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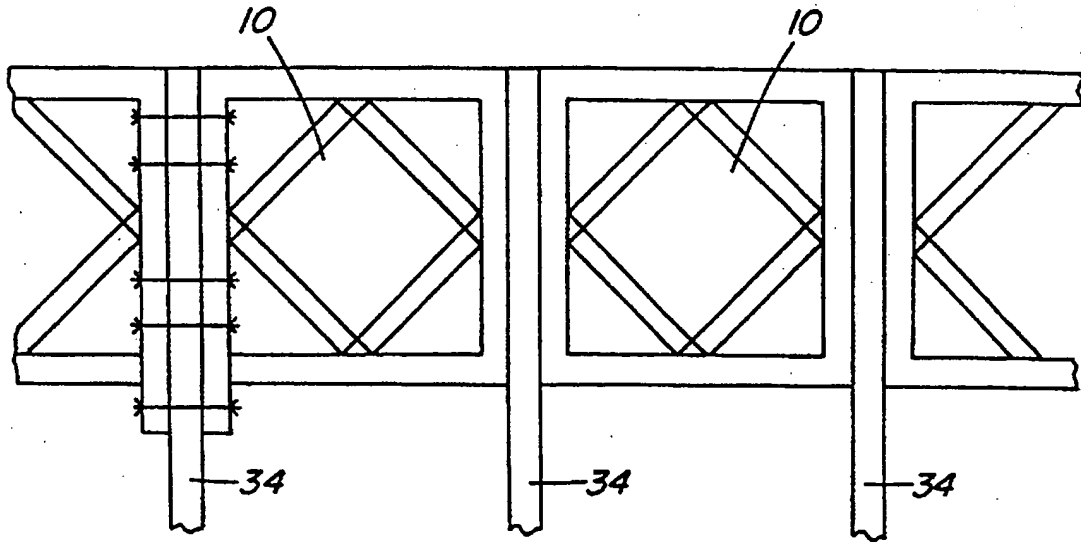


FIG. 9

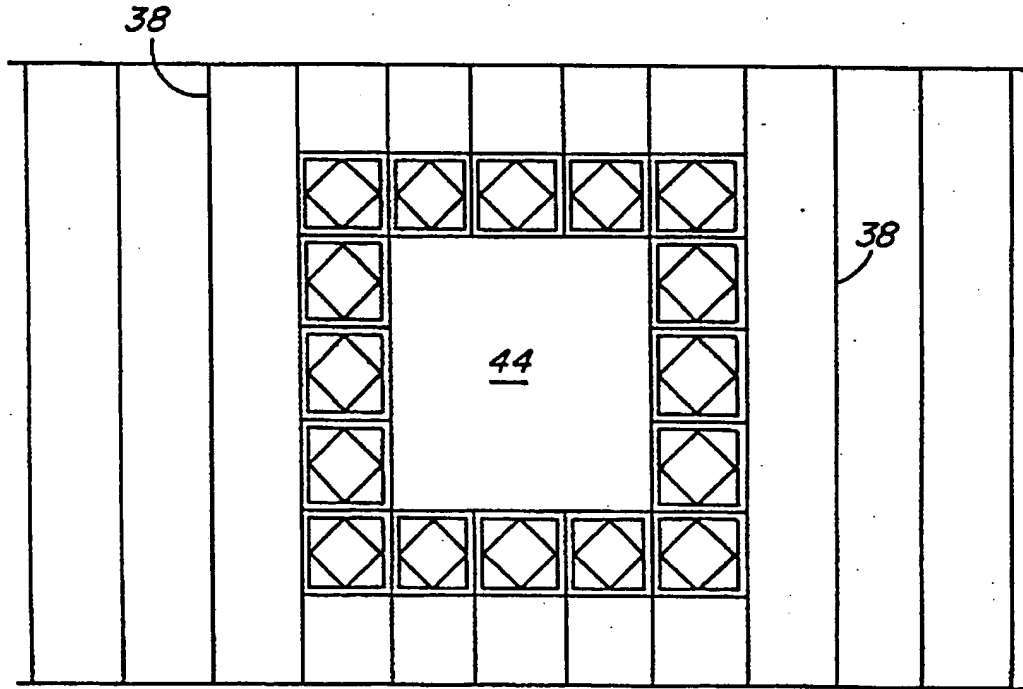


FIG. 10

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